CLAIMS

What is claimed is:

1   1. A Compton deconvolution camera comprising:

2   a first detection layer and a second detection layer, each to detect events

3   resulting from incident photons;

4   position sensing logic to determine positions of events in each of the first and

5   second detection layers;

6   a coincidence detector to detect pairs of coincident events resulting from

7   Compton scattering; and

8   processing logic to

9   for each of a plurality of subsets of the first detection layer, associate data

10   representing events detected for said subset with a distribution of corresponding events

11   in the second detection layer, based on said detected pairs of coincident events,

12   use a deconvolution function to localize probable source locations of

13   incident photons based on said distributions of corresponding events, and

14   use said probable source locations to reconstruct an image of an object.

1   2. A Compton deconvolution camera as recited in claim 1, wherein said deconvolution

2   is performed on the distribution of events in the second detection layer for each said

3   subset of the first detection layer.

1   3. A Compton deconvolution camera as recited in claim 2, wherein the processing logic

2   performs said association of data by computing Compton scattering angles for the

3   detected pairs of coincident events.

1   4. A Compton deconvolution camera as recited in claim 1, wherein the first detection

2   layer is disposed to receive incident photons from the object, and wherein no physical

3   collimator is used to collimate said incident photons.

1   5. A Compton deconvolution camera as recited in claim 4, wherein the image is

2   acquired using a single-photon emission mode.

1   6. A Compton deconvolution camera as recited in claim 4, wherein the processing logic

2   is configured to collimate the incident photons.

1   7. A Compton deconvolution camera as recited in claim 1, wherein each of the

2   detection layers comprises an array of solid-state ionization detectors.

1   8. A Compton deconvolution camera as recited in claim 1, wherein each of the

2   detection layers comprises a scintillator and an array of solid-state photodetectors.

1   9. A Compton deconvolution camera as recited in claim 1, wherein one of the detection

2   layers comprises an array of solid-state ionization detectors; and another of the

3   detection layers comprises a scintillator and an array of solid-state photodetectors.

1	10. A Compton deconvolution camera as recited in claim 1, wherein one of the

2	detection layers comprises an array of solid-state ionization detectors; and another of

3	the detection layers comprises a scintillator and an array of photomultiplier tubes.

1	11. A Compton deconvolution camera as recited in claim 1, wherein one of the

2	detection layers comprises a scintillator and an array of solid-state photodetectors; and

3	another of the detection layers comprises a scintillator and an array of photomultiplier

4	tubes.

1	12. A Compton deconvolution camera as recited in claim 1, wherein the processing

2	logic is configured to use measured values of absorbed energy in the detected events to

3	reject photons subjected to multiple Compton scattering.

1	13. A Compton deconvolution camera as recited in claim 1, wherein the processing

2	logic is configured to use measured values of absorbed energy in the detected events to

3	validate the computed Compton scattering angles.

1	14. A nuclear medicine imaging system comprising:

2	 a plurality of detector heads, each of the detector heads including two

3	substantially parallel detection layers to detect events resulting from incident gamma

4	rays originating from an object containing a radiopharmaceutical agent;

5	 position sensing logic to determine positions of events in each of the detection

6	layers;

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7   a coincidence detector to detect pairs of coincident events resulting from

8   Compton scattering, each pair including one event in each detection layer; and

9   processing logic to

10   for each of a plurality of subsets of one of the detection layers, forward-

11   project data representing detected events into a distribution of associated events in the

12   other detection layer, based on said detected pairs,

13   apply a deconvolution function to the forward-projected data to localize

14   probable source locations of incident gamma rays, and

15   use said probable source locations to reconstruct an image of the object.

1   15. A nuclear medicine imaging system as recited in claim 14, wherein no physical

2   collimator is used to collimate said incident gamma rays.

1   16. A nuclear medicine imaging system as recited in claim 15, wherein the image is

2   acquired using a single-photon emission mode.

1   17. A nuclear medicine imaging system as recited in claim 16, wherein the processing

2   logic is configured to collimate the incident gamma rays.

1   18. A nuclear medicine imaging system as recited in claim 14, wherein each of the

2   detection layers in each of the detector heads comprises an array of solid-state

3   ionization detectors.

1   19. A nuclear medicine imaging system as recited in claim 14, wherein each of the

2   detection layers in each of the detector heads comprises a scintillator and an array of

3   solid-state photodetectors.

1   20. A nuclear medicine imaging system as recited in claim 14, wherein:

2   one of the detection layers in each of the detector heads comprises an array of

3   solid-state ionization detectors; and

4   the other of the detection layers in each of the detector heads comprises a

5   scintillator and: an array of photodetectors.

1   21. A nuclear medicine imaging system as recited in claim 14, wherein the processing

2   logic is configured to use measured values of absorbed energy in the detected events to

3   reject photons subjected to multiple Compton scattering.

1   22. A nuclear medicine imaging system as recited in claim 14, wherein the processing

2   logic is configured to use measured values of absorbed energy in the detected events to

3   validate the computed Compton scattering angles.

1   23. A gamma camera comprising:

2   a plurality of detection layers, each to detect events resulting from incident

3   photons;

4   positioning means for determining positions of events in each of the detection

5   layers;

6 coincidence means for detecting pairs of coincident events resulting from

7 Compton scattering; and

8 forward-projection means for forward-projecting data representing detected

9 events, for each of a plurality of subsets of one of the detection layers, into a distribution

10 of corresponding events in the other detection layer, based on said detected pairs of

11 coincident events,

12 deconvolution means for applying a deconvolution function to the forward-

13 projected data to localize probable source locations of incident photons, and

14 reconstruction means for using said probable source locations to reconstruct an

15 image of an object.

1 24. A gamma camera as recited in claim 23, wherein the forward-projection means

2 comprises means for forward-projecting events in one of the detection layers

3 corresponding to a coincident event at a given pixel in another one of the detection

4 layers.

1 25. A gamma camera as recited in claim 23, wherein one of the detection layers is

2 disposed to receive incident photons from the object, and wherein no physical

3 collimator is used to collimate said incident photons.

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1   26. A gamma camera as recited in claim 25, wherein a second one of the detection

2   layers is disposed to receive photons that have undergone Compton scattering in the

3   first detection layer.

1   27. A gamma camera as recited in claim 26, wherein the reconstruction means

2   comprises means for reconstructing the image from a single-photon emission mode.

1   28. A gamma camera as recited in claim 27, further comprising means for collimating

2   the incident photons without using a physical collimator.

1   29. A gamma camera as recited in claim 24, wherein each of the detection layers each

2   comprises an array of solid-state ionization detectors.

1   30. A gamma camera as recited in claim 24, wherein each of the detection layers each

2   comprises a scintillator and an array of solid-state photodetectors.

1   31. A gamma camera as recited in claim 24, wherein one of the detection layers

2   comprises an array of solid-state ionization detectors; and another of the detection

3   layers comprises a scintillator and: an array of solid-state photodetectors or

4   photomultiplier tubes.

1   32. A gamma camera as recited in claim 24, further comprising means for using

2   measured values of absorbed energy in the detected events to reject photons subjected

3   to multiple Compton scattering.

1   33. A gamma camera as recited in claim 24, further comprising means for using

2   measured values of absorbed energy in the detected events to validate the computed

3   Compton scattering angles.

1   34. A Compton deconvolution camera comprising:

2   a first detection layer to detect events resulting from incident photons, at least

3   some of which undergo Compton scattering;

4   a second detection layer to detect events resulting from incident photons

5   Compton-scattered in the first detection layer;

6   first position sensing logic to determine positions of events in the first detection

7   layer, the first detection layer comprising a plurality of pixels;

8   second position sensing logic to determine positions of events in the second

9   detection layer;

10   a coincidence detector to detect pairs of coincident events, each pair including an

11   event in the first detection layer and an event in the second detection layer; and

12   processing logic to

13   for each pixel of the first detection layer, forward-project data

14   representing the detected events into a positional distribution of events in the second

15   detection layer,

16   apply a deconvolution function to the forward-projected data to localize

17   probable source locations of incident photons, and

18   use said probable source locations to reconstruct an image of an object.

1   35. A Compton deconvolution camera as recited in claim 34, wherein the

2   deconvolution function is applied to the collective forward-projected data for all pixels

3   of the first detection layer.

1   36. A Compton deconvolution camera as recited in claim 35, wherein no physical

2   collimator is used to collimate incident photons from the object.

1   37. A Compton deconvolution camera as recited in claim 36, wherein detection of said

2   events is performed using a single-photon emission mode.

1   38. A Compton deconvolution camera as recited in claim 36, wherein the processing

2   logic is configured to collimate the incident photons.

1   39. A Compton deconvolution camera as recited in claim 34, wherein the first and

2   second detection layers each comprise an array of solid-state ionization detectors.

1   40. A Compton deconvolution camera as recited in claim 34, wherein the first and

2   second detection layers each comprise a scintillator and an array of solid-state

3   photodetectors.

1   41. A Compton deconvolution camera as recited in claim 34, wherein:

2   one of the first and second detection layers comprises an array of solid-state

3   ionization detectors; and

4   the other of the first and second detection layers comprises a scintillator and an

5   array of solid-state photodetectors.

1   42. A Compton deconvolution camera as recited in claim 34, further comprising:

2   a first pulse height analyzer to measure the energy of events detected in the first

3   detection layer; and

4   a second pulse height analyzer to measure the energy of events detected in the

5   second detection layer.

1   43. A Compton deconvolution camera as recited in claim 34, wherein the processing

2   logic is configured to use measured values of absorbed energy in the detected events to

3   reject photons subjected to multiple Compton scattering.

1   44. A Compton deconvolution camera as recited in claim 34, wherein the processing

2   logic is configured to use measured values of absorbed energy in the detected events to

3   validate the computed Compton scattering angles.

1   45. A Compton deconvolution camera comprising:

2   a first detection layer to detect events resulting from incident photons from an

3   object to be imaged, wherein at least some of the incident photons undergo Compton

4   scattering in the first detection layer;

5   a second detection layer substantially parallel to the first detection layer, to

6   detect events resulting from photons Compton-scattered in the first detection layer;

7   first position sensing logic to determine two-dimensional positions of events in

8   the first detection layer;

9   second position sensing logic to determine two-dimensional positions of events

10   in the second detection layer;

11   a coincidence detector to detect pairs of coincident events, each pair including an

12   event in the first detection layer and an event in the second detection layer;

13   a first memory to store data representing a positional distribution of the events in

14   the first detection layer belonging to said pairs of coincident events, wherein the first

15   detection layer is represented as a plurality of two-dimensional locations,

16   a second memory; and

17   processing logic to

18   compute the Compton scattering angles for the detected pairs of

19   coincident events,

20   accumulate in the second memory, for each said two-dimensional location

21   of the first detection layer, a two-dimensional positional distribution of potentially

22   corresponding coincident events in the second detection layer,

23   apply a deconvolution function to the data in the second memory, for each

24   said two-dimensional location of the first detection layer, to localize probable origins of

25   the incident photons represented by said pairs of coincident events, and

26   backproject the processed data to reconstruct an image of the object.

1   46. A Compton deconvolution camera as recited in claim 45, wherein no physical

2   collimator is used to collimate said incident photons.

1   47. A Compton deconvolution camera as recited in claim 46, wherein the image is

2   acquired using a single-photon emission mode.

1   48. A Compton deconvolution camera as recited in claim 47, wherein the processing

2   logic is configured to collimate the incident photons.

1   49. A Compton deconvolution camera as recited in claim 45, wherein the first and

2   second detection layers each comprise an array of solid-state ionization detectors.

1   50. A Compton deconvolution camera as recited in claim 45, wherein the first and

2   second detection layers each comprise a scintillator and an array of solid-state

3   photodetectors.

1   51. A Compton deconvolution camera as recited in claim 45, wherein:

2   one of the first and second detection layers comprises an array of solid-state

3   ionization detectors; and

4   the other of the first and second detection layers comprises a scintillator and an

5   array of photodetectors.

1   52. A Compton deconvolution camera as recited in claim 45, further comprising:

2   a first pulse height analyzer to measure the energy of events detected in the first

3   detection layer; and

4   a second pulse height analyzer to measure the energy of events detected in the

5   second detection layer.

1   53. A Compton deconvolution camera as recited in claim 45, wherein the processing

2   logic is configured to use measured values of absorbed energy in the detected events to

3   reject photons subjected to multiple Compton scattering.

1   54. A Compton deconvolution camera as recited in claim 45, wherein the processing

2   logic is configured to use measured values of absorbed energy in the detected events to

3   validate the computed Compton scattering angles.

1   55. A Compton deconvolution camera comprising:

2   a first detection layer to detect events resulting from incident photons from an

3   object to be imaged, wherein at least some of the incident photons undergo Compton

4   scattering in the first detection layer;

5   a second detection layer substantially parallel to the first detection layer, to

6   detect events resulting from photons Compton-scattered in the first detection layer;

7   a first set of amplifiers to amplify outputs of the first detection layer;

8   a second set of amplifiers to amplify outputs of the second detection layer;

9   a first set of analog-to-digital (A/D) converters to digitize the amplified outputs

10   of the first set of preamplifiers;

11   a second set of analog-to-digital (A/D) converters to digitize the amplified

12   outputs of the second set of preamplifiers;

13   first position sensing logic coupled to receive the digitized, amplified outputs of

14   the first detection layer, to determine two-dimensional positions of events in the first

15   detection layer;

16   second position sensing logic coupled to receive the digitized, amplified outputs

17   of the second detection layer, to determine two-dimensional positions of events in the

18   second detection layer;

19   a coincidence detector to detect pairs of coincident events, each pair including an

20   event in the first detection layer and an event in the second detection layer;

21   a first pulse height analyzer to measure the energy of events detected in the first

22   detection layer;

23   a second pulse height analyzer to measure the energy of events detected in the

24   second detection layer;

25   a first memory to store data representing a two-dimensional positional

26   distribution of the events in the first detection layer belonging to said pairs of

27   coincident events, wherein the first detection layer is represented as a plurality of

28   pixels,

29   a second memory; and

30   processing logic to

31   accumulate in the second memory, for each pixel of the first detection

32   layer, a two-dimensional positional distribution of potentially corresponding coincident

33   events in the second detection layer,

34   process the data in the second memory by applying a deconvolution

35   function, for all pixels of the first detection layer, to localize probable origins of the

36   incident photons represented by the pairs of coincident events,

37   compute the Compton scattering angles for the detected pairs of

38   coincident events, and

39   back project the processed data to reconstruct an image of the object.

1   56. A Compton deconvolution camera as recited in claim 55, wherein no physical

2   collimator is used to collimate said incident photons.

1   57. A Compton deconvolution camera as recited in claim 56, wherein the image is

2   acquired using a single-photon emission mode.

1   58. A Compton deconvolution camera as recited in claim 56, wherein the processing

2   logic is configured to collimate the incident photons.

1   59. A Compton deconvolution camera as recited in claim 55, wherein the first and

2   second detection layers each comprise an array of solid-state ionization detectors.

1   60. A Compton deconvolution camera as recited in claim 55, wherein the first and

2   second detection layers each comprise a scintillator and an array of solid-state

3   photodetectors.

1   61. A Compton deconvolution camera as recited in claim 55, wherein:

2   one of the first and second detection layers comprises an array of solid-state

3   ionization detectors; and

4   the other of the first and second detection layers comprises a scintillator and an

5   array of photodetectors.

1   62. A Compton deconvolution camera as recited in claim 55, wherein the processing

2   logic is configured to use measured values of absorbed energy in the detected events to

3   reject photons subjected to multiple Compton scattering.

1   63. A Compton deconvolution camera as recited in claim 55, wherein the processing

2   logic is configured to use measured values of absorbed energy in the detected events to

3   validate the computed Compton scattering angles.

1   64. A method of generating an image of an object, the method comprising:

2   using a plurality of substantially parallel detection layers to detect events

3   resulting from incident photons, without using a physical collimator;

4   determining positions of the events in each of the detection layers;

5   identifying pairs of said events occurring in coincidence, said pairs resulting

6   from Compton scattering, each said pair including one event from each of the detection

7   layers;

8   forward-projecting data representing detected events, for each of a plurality of

9   subsets of one of the detection layers, into a distribution of corresponding events in the

10   other detection layer, based on said detected pairs of coincident events;

11   using a deconvolution function to localize probable source locations of incident

12   photons; and

13   using the probable source locations to reconstruct an image of an object.

1   65. A method as recited in claim 64, wherein said using a plurality of substantially

2   parallel detection layers to detect events comprises detecting events in a single-photon

3   mode.

1 66. A method as recited in claim 64, further comprising electronically collimating the

2 incident photons.

1 67. A method as recited in claim 64, wherein said forward-projecting comprises

2 forward-projecting a pattern of scintillation events in the second detection layer

3 corresponding to coincident events at a given pixel in the first detection layer.

1 68. A method as recited in claim 64, wherein each of the detection layers each

2 comprises an array of solid-state ionization detectors.

1 69. A method as recited in claim 64, wherein each of the detection layers each

2 comprises a scintillator and an array of solid-state photodetectors.

1 70. A method as recited in claim 64, wherein one of the detection layers comprises an

2 array of solid-state ionization detectors, and another of the detection layers comprises a

3 scintillator and: an array of solid-state photodetectors or photomultipliers.

1 71. A method as recited in claim 64, further comprising using measured values of

2 absorbed energy in the detected events to reject photons subjected to multiple Compton

3 scattering.

1   72. A method as recited in claim 64, further comprising using measured values of

2   absorbed energy in the detected events to validate the computed Compton scattering

3   angles.